

TITLE OF THE INVENTION

LASER PROCESSING METHOD AND APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

5 This application is based upon and claims the benefit of priority from the prior Japanese Patent Application No. 2001-032708, filed February 8, 2001, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

10 1. Field of the Invention

The present invention relates to a manufacturing process, for example, of a polysilicon (p-Si) thin film transistor (TFT) liquid crystal display, and to a laser processing method and apparatus in which a workpiece
15 such as an amorphous silicon (a-Si) film is irradiated with a pulse laser beam, and the a-Si film is polycrystallized.

2. Description of the Related Art

A manufacturing process of a p-Si TFT liquid
20 crystal display includes a process of polycrystallization. The process includes: forming an a-Si thin film on a glass substrate of the liquid crystal display; and forming the thin film into a polycrystalline silicon (Si) film.

25 Examples of a method of poly-crystallization include a solid phase growth method and an excimer laser annealing method. The solid phase growth method

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includes annealing the a-Si film formed on the glass substrate at a high temperature so that a polycrystalline Si film is obtained. Since the solid phase growth method is a high-temperature process, it is necessary to use an expensive quartz glass in the glass substrate.

The excimer laser annealing method includes irradiating the a-Si film with a short-pulse excimer laser having a pulse width of about 20 ns so that the polycrystalline Si film is obtained. Since the excimer laser annealing method is a low-temperature process, mass production can be realized.

In the p-Si TFT liquid crystal display, an enhanced capability has been requested to be realized. To realize the enhanced capability, there has been a stronger demand for further enlargement of a current crystal particle diameter of the polycrystalline Si film. Concretely, the crystal particle diameter is around 0.5 μm in the current method, and there has been a strong demand for setting of the diameter to several micrometers or more.

Reasons for this will be described. There is a numeric value of mobility as a factor which influences the capability of a semiconductor device. The mobility represents a movement speed of an electron. The movement speed drops, when the crystal particle diameter is small and there are many crystal particle

fields in a path of the electron. When the movement speed decreases, the enhanced capability of the semiconductor device cannot be expected. Therefore, there is a demand for enlargement of the crystal particle diameter of the polycrystalline Si film.

Examples of an enlargement method of the crystal particle diameter include techniques described, for example, in Jpn. Pat. Appln. KOKAI Publication No. 56-137546 and PCT National Publication No. 2000-505241. The Jpn. Pat. Appln. KOKAI Publication No. 56-137546 discloses a method for using a roof-shaped laser beam to scan a work. The PCT National Publication No. 2000-505241 discloses a method called super lateral growth.

These methods include: successively irradiating an Si thin film with a laser beam having a linear or roof-shaped pattern in synchronization with movement of the Si thin film, that is, the glass substrate. The present inventors have verified that the crystal particle diameter of the polycrystalline Si film is enlarged by these methods.

However, in these methods, since the Si thin film is successively irradiated with the laser beam at an interval, the glass substrate has to be moved for each irradiation with the laser beam. A movement distance needs to be between about 0.1 μm and 1.0 μm .

Therefore, in order to form the Si thin film into

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the polycrystalline Si film on a large-sized glass substrate, for example, a 300 mm x 400 mm glass substrate, the glass substrate has to be moved at an interval of about 0.1 μ m to 1.0 μ m. To form the polycrystalline Si film over the large-sized glass substrate, a throughput of several hours is required, and formation cannot be realized.

Examples of a method for forming the polycrystalline Si film at a higher speed include a method described in Jpn. Pat. Appln. No. 9-217213. This method includes: forming a plurality of repeated patterns 1 on a mask as shown in FIG. 1; and moving the glass substrate by a pitch of the pattern 1.

Subsequently, the glass substrate is irradiated with the laser beam through the mask. In a region irradiated with the laser beam, a crystal grows, and the whole region irradiated with the laser beam is poly-crystallized. FIG. 1 shows a crystal grown region 2.

Subsequently, the glass substrate is moved in a stepwise manner by the region irradiated with the laser beam.

Subsequently, the glass substrate is irradiated with the laser beam through the mask. In the region irradiated with the laser beam, the crystal grows, and the whole region irradiated with the laser beam is poly-crystallized.

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Thereafter, the irradiation with the laser beam and the stepwise movement of the glass substrate are repeated, and the whole glass substrate is polycrystallized.

5 There is another method for forming the polycrystalline Si film at a high speed. In the method, the pitch of the pattern 1 formed on the mask is reduced as shown in FIG. 2, and the glass substrate is not moved. This mask is used to grow the crystal in
10 a region portion irradiated with the laser beam.

 The method includes: using the mask with the repeated pattern, for example, having a pattern width of 2 μm and pitch of μm formed thereon to form, for example, a polycrystal having a length of 2 μm and
15 width of 0.3 μm .

 However, the former method requires a throughput of several hours, is unrealistic, and has a low productivity. In this method, when a width of the laser beam is set, for example, to 5 μm or more as
20 shown in FIG. 3, a heat gradient of a middle portion in the region irradiated with the laser beam is reduced.

 Therefore, boundaries of opposite ends of the region irradiated with the laser beam have a large particle diameter, but the middle portion is micro-crystallized. Then, a transistor is formed on the
25 crystallized region, but the micro-crystallization forms an Si crystal film which inhibits enhancement of

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the capability of the transistor.

In the latter method, there are large influences of a stop operation in a substrate conveyance system for moving the glass substrate in the stepwise manner, deceleration operation during restart, and an acceleration time. Therefore, the throughput in an actual mass production line is not achieved, and a further high-speed processing is necessary.

In the latter method for narrowing the pitch of the pattern 1, because of a heat influence from the adjacent pattern 1, a growth speed of a lateral direction (vertical to a film thickness direction) of the Si film is lowered. Therefore, in the latter method, a part of the region irradiated with the laser beam, for example, the middle portion of the irradiated region is micro-crystallized, and a micro crystal region 3 is formed as shown in FIG. 2.

Furthermore, when the pitch of the repeated pattern 1 is narrowed, the whole surface of the region irradiated with the laser beam is micro-crystallized, and the mobility of the electron is lowered as shown in FIG. 4.

BRIEF SUMMARY OF THE INVENTION

An object of the present invention is to provide a laser processing method and apparatus in which a polycrystalline Si film having a uniform and large particle diameter can be formed with a high throughput.

According to a major aspect of the present invention, there is provided a laser processing method for irradiating a mask with a plurality of openings formed therein with a pulse laser, and irradiating a plurality of portions of a work to be processed with the pulse laser transmitted through the plurality of openings at the same time. The method comprises: moving a mask and a work with respect to each other while emitting the pulse laser a plurality of times; and setting a relation between a relative movement speed of the mask and the work and an emission timing of the pulse laser such that respective laser irradiated regions disposed adjacent to one another on the work are formed by irradiation with the pulse laser transmitted through the openings formed in positions different from one another on the mask, and boundaries of the respective laser irradiated regions disposed adjacent to each other contact at least each other.

According to another major aspect of the present invention, there is provided a laser processing apparatus for irradiating a mask with a plurality of openings formed therein with a pulse laser, and irradiating a plurality of portions of a work to be processed with the pulse laser transmitted through the plurality of openings at the same time. The apparatus comprises: a laser device for outputting the pulse laser; a moving section which moves the mask and the

work with respect to each another; and a controller which controls the moving section to move the mask and the work with respect to each other, and controls the laser device to emit the pulse laser a plurality of times. The controller controls the moving section to move the mask and the work with respect to each other so that respective laser irradiated regions disposed adjacent to one another are irradiated with the pulse laser transmitted through the openings different from one another among the plurality of openings, and boundaries of the respective laser irradiated regions disposed adjacent to each other contact at least each other.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

FIG. 1 is a schematic view showing a conventional method for forming a polycrystalline Si film;

FIG. 2 is a schematic view showing a conventional method for narrowing a pitch of a repeated pattern and forming the polycrystalline Si film;

FIG. 3 is a schematic view showing a relation between a conventional laser beam width and micro crystal generation;

FIG. 4 is a schematic view showing a conventional method for narrowing the pitch of the repeated pattern and forming the polycrystalline Si film;

FIG. 5 is a constitution diagram showing a laser processing apparatus according to a first embodiment of

the present invention;

FIG. 6 is a constitution diagram of a mask in the laser processing apparatus according to the first embodiment of the present invention;

5 FIG. 7 is a diagram showing a region crystallized by a first shot of pulse laser beam;

FIG. 8 is a diagram showing a region crystallized by a second shot of pulse laser beam;

10 FIG. 9 is a diagram showing a region crystallized by a third shot of pulse laser beam;

FIG. 10 is a diagram showing a region crystallized by a fourth shot of pulse laser beam;

FIG. 11 is a diagram showing a region crystallized by a fifth shot of pulse laser beam;

15 FIG. 12 is a constitution diagram of the mask in the laser processing apparatus according to a second embodiment of the present invention;

FIG. 13 is a diagram showing the region crystallized by the first shot of pulse laser beam;

20 FIG. 14 is a diagram showing the region crystallized by the second shot of pulse laser beam;

FIG. 15 is a diagram showing the region crystallized by the third shot of pulse laser beam;

25 FIG. 16 is a diagram showing the region crystallized by the fourth shot of pulse laser beam;

FIG. 17 is a diagram showing the region crystallized by the fifth shot of pulse laser beam;

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FIG. 19 is a diagram showing the region
5 crystallized by the first shot of pulse laser beam;

FIG. 20 is a diagram showing the region
crystallized by the second shot of pulse laser beam;

FIG. 21 is a diagram showing the region
crystallized by the third shot of pulse laser beam;

FIG. 22 is a constitution diagram of the mask in the laser processing apparatus according to a fourth embodiment of the present invention;

15 FIG. 24 is a diagram showing the region
crystallized by the second shot of pulse laser beam;

FIG. 25 is a diagram showing the region
crystallized by the third shot of pulse laser beam;

FIG. 26 is a constitution diagram of the mask in
20 the laser processing apparatus according to a fifth
embodiment of the present invention;

25 FIG. 28 is a constitution diagram of the mask in
the laser processing apparatus according to a sixth
embodiment of the present invention;

FIG. 30 is a constitution diagram of the mask in
the laser processing apparatus according to a seventh
embodiment of the present invention;

FIG. 32 is a diagram showing the region
10 crystallized by the second shot of pulse laser beam;

FIG. 34 is a diagram showing an overlap of the regions irradiated with the respective shots of laser;

FIG. 36 is an explanatory view of the manu-
facturing method of another TFT liquid crystal display
to which the laser processing apparatus of an eighth
embodiment of the present invention is applied;

FIG. 38 is a schematic view showing a first exposure processing in the exposure device;

FIG. 39 is a schematic view showing a second exposure processing in the exposure device;

FIG. 40 is a schematic view showing a transfer result in the exposure device; and

5 FIG. 41 is a schematic view showing a transfer action by a conventional exposure device.

DETAILED DESCRIPTION OF THE INVENTION

10 A first embodiment of the present invention will be described hereinafter with reference to the drawings.

15 FIG. 5 is a constitution diagram of a laser processing apparatus. The laser processing apparatus is applied to manufacturing of a p-Si TFT liquid crystal display which has a process of poly-crystallization of an a-Si film formed on a glass substrate 10.

20 An excimer laser 11 outputs a pulse laser, for example, at a repeated frequency of 200 to 500 Hz. The excimer laser 11 outputs the pulse laser whose energy density of an irradiated point on the a-Si film is of the order of 200 to 500 J/cm². The point irradiated with the pulse laser forms a processed point on the a-Si film.

25 A variable attenuator 12, lighting optical system 13, mask 14, and mirror 15 are disposed along an optical path of the pulse laser. A projection lens 16 is disposed on a reflected light path of the mirror 15.

The lighting optical system 13 is constituted of a homogenizer, and a beam shaping optical system of the pulse laser beam. Concretely, the lighting optical system 13 includes a collimator lens 17, array lens group 18, and field lens 19.

The homogenizer forms the pulse laser beam as a beam having a uniform strength on the mask 14. The homogenizer is formed by a combination of the field lens 19 and array lens group 18.

The projection lens 16 transfers a mask pattern formed on the mask 14 onto the a-Si film.

Eight line patterns 20 as openings are formed in the same direction in the mask 14. A width and pitch of the line pattern 20 is formed in sizes to form a polycrystalline Si film having a predetermined or larger crystal particle diameter, when the a-Si film is irradiated with the pulse laser and poly-crystallized.

The width of each line pattern 20 is formed in such a line width length that a heat gradient is generated in the laser irradiated region obtained by irradiating the a-Si film with the pulse laser. The pitch between the line patterns 20 is formed in a pitch interval such that the heat gradient is generated in the laser irradiated region obtained, when irradiating the a-Si film with the pulse laser.

A constitution of the mask 14 will concretely be described with reference to FIG. 6.

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The mask 14 is divided into a plurality of regions, for example, first to fourth mask regions M_1 to M_4 . An interval among these mask regions M_1 to M_4 is formed in an interval having an equal pitch M_p .

5 The respective line patterns 20 are formed in positions which do not overlap one another in the respective mask regions M_1 to M_4 .

10 For description of the position of each line pattern 20, respective origins Z_1 to Z_4 are disposed with respect to the mask regions M_1 to M_4 . The respective line patterns 20 are formed in positions having different distances from the origins Z_1 to Z_4 in the mask regions M_1 to M_4 .

15 For example, two line patterns 20 are separate from each other by a predetermined pitch in the mask region M_1 , and the line pattern 20 on the right side in the drawing is formed in a position aligned with the origin Z_1 .

20 In the mask region M_2 , two line patterns 20 are separate from each other by the same pitch as the pitch of the line patterns 20 of the mask region M_1 , and are formed on the left side of the origin Z_2 , for example, by a line pattern width.

25 In the mask region M_3 , two line patterns 20 are separate from each other by the same pitch as the pitch of the line patterns 20 of the mask region M_1 , and are formed on the left side from the origin Z_3 , for

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example, by a length twice that of the line pattern width.

In the mask region M_4 , two line patterns 20 are separate from each other by the same pitch as the pitch of the line patterns 20 of the mask region M_1 , and are formed on the left side from the origin Z_4 , for example, by a length three times that of the line pattern width. In the mask region M_4 , the shown left line pattern 20 is formed on the leftmost side of the mask region M_4 .

Each line pattern 20 is formed so that the laser irradiated region on the a-Si film has, for example, a beam width of about 5 μm or less and a pitch of 1 μm or more.

For a condition for forming the polycrystalline Si film having a predetermined or larger crystal particle diameter, the laser irradiated region on the a-Si film has each beam width of about 5 μm or less and a pitch M_p of 1 μm or more.

The condition that the beam width is 5 μm or less influences a thickness of the a-Si film formed on the glass substrate 10. When the a-Si film is irradiated, for example, with a single line beam, the crystal grows toward a middle portion from an outer edge of the line beam, and the whole surface of the laser irradiated region is poly-crystallized on this condition.

The condition that the pitch M_p of the beam width

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is 1 μm or more is influenced by the width of the line beam and the thickness of the a-Si film, and changes. This condition undergoes a heat influence from the adjacent line pattern, unless the interval of the
5 respective line beams is 1 μm or more based on at least a general resolution and heat diffusion distance of the optical system.

The glass substrate 10 is laid on an XYZ tilt stage 21. The XYZ tilt stage 21 moves the glass
10 substrate 10 in X, Y, and Z directions. The X, Y, and Z directions cross at right angles to one another. The XYZ tilt stage 21 raster-scans the pulse laser on the glass substrate 10 by the movement of the XYZ directions.

15 Concretely, the XYZ tilt stage 21 moves, for example, the glass substrate 10 continuously in the X direction at a conveyance speed synchronized with the repeated frequency of the pulse laser. In this case, the conveyance direction is a positive or negative X
20 direction.

Moreover, the XYZ tilt stage 21 moves the glass substrate 10 in the Y direction by a distance corresponding to the width of the pulse laser beam.

Subsequently, the XYZ tilt stage 21 again moves
25 the glass substrate 10 continuously in the X direction at the conveyance speed synchronized with the repeated frequency of the pulse laser. In this case, the X

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direction of the conveyance is reverse to the previous X direction, that is, the negative or positive X direction.

5 Thereafter, the XYZ tilt stage 21 repeats the
aforementioned movement.

The XYZ tilt stage 21 moves the glass substrate 10, for example, at a conveyance speed of about 200 to 500 mm/s.

10 A controller 22 controls the XYZ tilt stage 21 to
move the glass substrate 10 at a constant speed so that
the pulse laser raster-scans the glass substrate 10.
Moreover, the controller 22 controls the excimer laser
11 to emit the pulse laser at a constant timing a
plurality of times.

15 The controller 22 irradiates the respective laser
irradiated regions disposed adjacent to one another on
the a-Si film with the pulse laser transmitted through
the different line patterns 20. Moreover, the
controller 22 moves the glass substrate 10 so that the
20 respective boundaries of the laser irradiated regions
adjacent to one another contact one another.

25 A focus displacement meter 23 measures
displacement with the a-Si film on the glass substrate
10, and feeds a displacement signal back to the XYZ
tilt stage 21. The XYZ tilt stage 21 vertically moves
the glass substrate 10 in the Z direction based on the
fed-back displacement signal. Thereby, an image of a

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mask pattern is formed on the a-Si film on the glass substrate 10.

An operation of the apparatus constituted as described above will next be described.

5 A manufacturing process of a p-Si TFT liquid crystal display includes a photolithography process. The photolithography process includes a process of forming an a-Si thin film on the glass substrate 10, a process of coating the thin film with a resist, a
10 process of performing an exposure processing, a developing process, a process of an etching processing, and a process of removing the resist.

 The photolithography process includes a process of poly-crystallizing the a-Si film on the glass
15 substrate 10.

 The method of poly-crystallizing the a-Si film on the glass substrate 10 is carried out as follows.

 The excimer laser 11 intermittently outputs the pulse laser, for example, at a repeated frequency of
20 200 to 500 Hz. The pulse laser is emitted to the mask 14 from the variable attenuator 12 through the lighting optical system 13.

 The pulse laser is passed through the mask pattern formed on the mask 14, reaches the mirror 15, and is
25 reflected by the mirror 15. The pulse laser reflected by the mirror 15 is emitted onto the a-Si film on the glass substrate 10 by the projection lens 16.

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Moreover, the XYZ tilt stage 21 moves the glass substrate 10 in the X direction at the conveyance speed synchronized with the repeated frequency of the pulse laser beam. In this case, the conveyance direction is the positive or negative X direction.

Subsequently, the XYZ tilt stage 21 moves the glass substrate 10 in the Y direction by a distance corresponding to the width of the pulse laser beam.

Next, the XYZ tilt stage 21 again moves the glass substrate 10 continuously in the X direction. In this case, the conveyance direction is the negative or positive X direction.

Thereafter, the XYZ tilt stage 21 repeats the aforementioned movement.

The XYZ tilt stage 21 moves the glass substrate 10, for example, at the conveyance speed of about 200 to 500 mm/s.

The a-Si film on the glass substrate 10 is irradiated with first, second, third, ... shots of pulse laser beams output from the excimer laser 11 through the mask 14.

FIG. 7 shows each laser irradiated region Q_1 polycrystallized when the a-Si film is irradiated with the first shot of pulse laser beam. The pulse laser beam passed through each line pattern 20 of the mask 14 is emitted onto the a-Si film on the glass substrate 10. The a-Si film of the laser irradiated region Q_1 is

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poly-crystallized by these pulse laser beams.

Each laser irradiated region Q_1 is set such that each beam width is $5\text{ }\mu\text{m}$ or less and the pitch M_p is $1\text{ }\mu\text{m}$ or more. Thereby, in each laser irradiated region Q_1 , the crystal grows toward the middle portion from the outer edge of the laser irradiated region, and the whole surface of the laser irradiated region Q_1 is poly-crystallized to form the polycrystalline Si film having the predetermined or larger crystal particle diameter.

Each laser irradiated region Q_1 does not undergo any heat influence from the adjacent laser irradiated region, and the a-Si film is poly-crystallized.

Subsequently, FIG. 8 shows a laser irradiated region Q_2 poly-crystallized when the a-Si film is irradiated with the second shot of pulse laser beam.

Here, a region W_1 irradiated with the first shot of pulse laser will be noted in the following description.

At the second shot, the first mask region M_1 moves toward the left side in the drawing from the position irradiated with the first shot of pulse laser.

Therefore, the region Q_2 irradiated with the second shot of laser is adjacent to the laser irradiated region Q_1 poly-crystallized by the pulse laser beam passed through each line pattern 20 of the second mask region M_2 at the first shot.

Here, the laser irradiated regions Q_1 and Q_2 are formed by the pulse laser passed through the different line patterns 20, not by the pulse laser passed through the same line pattern 20.

5 Therefore, in the region W_1 , the laser irradiated region Q_2 at the second shot does not undergo any heat influence from the adjacent laser irradiated region. The laser irradiated region Q_2 is obtained by poly-crystallizing the a-Si film in the predetermined or
10 larger crystal particle diameter.

Next, FIG. 9 shows a laser irradiated region Q_3 poly-crystallized when the a-Si film is irradiated with the third shot of pulse laser.

15 In the region W_1 , the first mask region M_1 further moves toward the left side in the drawing from the position irradiated with the second shot of pulse laser.

Therefore, the laser irradiated region Q_3 at the third shot is adjacent to the region Q_2 poly-crystallized by the pulse laser beam passed through
20 each line pattern 20 of the second mask region M_2 at the second shot.

The laser irradiated region Q_3 at the third shot does not undergo any heat influence from the adjacent
25 laser irradiated region, and the a-Si film is poly-crystallized in the predetermined or larger crystal particle diameter.

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Thereafter, similarly as described above, the pulse laser is emitted onto the a-Si film on the glass substrate 10 through the mask 14, and the glass substrate 10 is continuously moved by the operation of the XYZ tilt stage 21.

FIG. 10 shows a laser irradiated region Q₄ poly-crystallized by a fourth shot of pulse laser beam.

FIG. 11 shows a laser irradiated region Q₅ poly-crystallized by a fifth shot of pulse laser beam.

These regions Q₄, Q₅ do not undergo any heat influence from the adjacent laser irradiated region, and the a-Si film is poly-crystallized in the predetermined or larger crystal particle diameter.

Therefore, for the a-Si film on the glass substrate 10, a non laser irradiated region not irradiated with the pulse laser is successively filled up, and finally the whole surface of the a-Si film on the glass substrate 10 is poly-crystallized.

As described, in the first embodiment, the mask 14 is used in which the width of the line pattern 20 has a slit width to generate the heat gradient in the laser irradiated region obtained when irradiating the a-Si film with the pulse laser, and the pitch is formed in a pitch interval to generate the heat gradient in the laser irradiated region. The pulse laser is emitted onto the glass substrate 10 at a timing corresponding to the conveyance speed of the glass substrate 10. The

a-Si film on the glass substrate 10 is irradiated with the pulse laser through the mask 14, and the glass substrate 10 is continuously moved by the operation of the XYZ tilt stage 21.

5 Thereby, while the glass substrate 10 is continuously moved, the a-Si film on the glass substrate 10 can continuously be formed into the polycrystalline Si film having the uniform and predetermined or larger crystal particle diameter.

10 Therefore, the polycrystalline Si film can be formed at the high speed. Mobility of an electron can be enhanced by forming the polycrystalline Si film having the large crystal particle diameter. For example, a capability of a transistor formed on the Si
15 crystallized film is enhanced, and the capability of the p-Si TFT liquid crystal display can be enhanced.

 In the manufacturing process of the p-Si TFT liquid crystal display, productivity in poly-crystallizing the a-Si film on the glass substrate 10
20 can be enhanced. Thereby, a high throughput can be obtained.

 To poly-crystallize the a-Si film on the whole surface of the glass substrate 10, when the XYZ tilt stage 21 continuously moves the glass substrate 10 in
25 the X direction, subsequently moves the glass substrate 10 in the Y direction, and again moves the substrate continuously in the X direction, an action of

poly-crystallization is temporarily stopped. This is a natural operation from the shape of the glass substrate 10.

5 A second embodiment of the present invention will next be described with reference to the drawings.

10 In the laser processing apparatus of the second embodiment, the mask 14 shown in FIG. 5 is modified. Therefore, the laser processing apparatus will be described using the laser processing apparatus shown in FIG. 5.

FIG. 12 is a constitution diagram of a mask 30 for use in the laser processing apparatus.

15 In the mask 30, square patterns 31 as openings are formed in the same direction. The width and pitch of the square pattern 31 are formed in the sizes to form the polycrystalline Si film having the predetermined or larger crystal particle diameter, when the a-Si film is irradiated with the pulse laser and poly-crystallized.

20 The width of each square pattern 31 is formed in a slit width length to generate the heat gradient in the laser irradiated region, when the a-Si film is irradiated with the pulse laser. The pitch between the square patterns 31 is formed in the pitch interval to generate the heat gradient in the laser irradiated
25 region, when the a-Si film is irradiated with the pulse laser.

A constitution of the mask 30 will concretely be

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described.

The mask 30 is divided into a plurality of divided regions, for example, first to fourth mask regions M_{11} to M_{14} . Each interval among these mask regions M_{11} to M_{14} is formed in the interval having the equal pitch M_p .

The respective square patterns 31 are formed in positions which do not overlap one another in the respective mask regions M_{11} to M_{14} .

For the description of the position of each square pattern 31, respective origins Z_{11} to Z_{14} are disposed with respect to the mask regions M_{11} to M_{14} . The respective square patterns 31 are formed in positions having different distances from the origins Z_{11} to Z_{14} in the mask regions M_{11} to M_{14} .

For example, in the mask region M_{11} , the plurality of square patterns 31 are arranged in two rows in the Y direction. These square patterns 31 are separated from one another at a predetermined pitch in the X and Y directions, and the square pattern 31 on the right side in the drawing is aligned with the origin Z_{11} .

In the mask region M_{12} , the plurality of square patterns 31 are arranged in two rows in the Y direction. These square patterns 31 are separated from one another at the predetermined pitch in the X and Y directions, and the square pattern 31 on the right side in the drawing is formed in a position apart from the

origin Z_{12} by a predetermined pitch in the Y direction.

In the mask region M_{13} , the plurality of square patterns 31 are arranged in two rows in the Y direction. These square patterns 31 are separated from one another at the predetermined pitch in the X and Y directions, and the square pattern 31 on the right side in the drawing is formed in a position apart from the origin Z_{13} by the predetermined pitch in the X and Y directions.

In the mask region M_{14} , the plurality of square patterns 31 are arranged in two rows in the Y direction. These square patterns 31 are separated from one another at the predetermined pitch in the X and Y directions, and the square pattern 31 on the right side in the drawing is formed in a position apart from the origin Z_{14} by the predetermined pitch in the X direction.

The width and pitch of the square pattern 31 have values such that the heat gradient is generated in the laser irradiated region in the a-Si film formed on the glass substrate 10. For example, the beam width of the laser irradiated region on the a-Si film is set to about $5\text{ }\mu\text{m}$ or less, and the pitch is set to about $5\text{ }\mu\text{m}$ or more.

An operation of the apparatus constituted as described above will next be described.

The excimer laser 11 intermittently outputs the

pulse laser, for example, at a repeated frequency of 200 to 500 Hz. The pulse laser is emitted to the mask 30 from the variable attenuator 12 through the lighting optical system 13.

5 The pulse laser is passed through the mask pattern formed on the mask 30, reaches the mirror 15, and is reflected by the mirror 15. The pulse laser reflected by the mirror 15 is emitted onto the a-Si film on the glass substrate 10 by the projection lens 16.

10 Moreover, similarly as the first embodiment, the XYZ tilt stage 21 continuously moves the glass substrate 10 at the conveyance speed synchronized with the repeated frequency of the pulse laser beam.

15 The first, second, third, ... shots of pulse laser beams output from the excimer laser 11 are emitted onto the a-Si film on the glass substrate 10 through the mask 30.

20 FIG. 13 shows each square laser irradiated region A poly-crystallized when the a-Si film is irradiated with the first shot of pulse laser beam. The a-Si film on the glass substrate 10 is irradiated with the pulse laser beams passed through the respective square patterns 31 of the mask 30. The a-Si film of the laser irradiated region A with these pulse laser beams is
25 poly-crystallized.

 In each laser irradiated region A, the beam width is set to 5 μm or less, and the pitch M_p is set to 5 μm

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or more. Thereby, in the laser irradiated region A, the crystal grows toward the middle portion from the outer edge, and the whole surface of the laser irradiated region A is poly-crystallized to form the polycrystalline Si film having the predetermined or larger crystal particle diameter.

In each laser irradiated region A, the a-Si film is poly-crystallized without undergoing any heat influence from the adjacent laser irradiated region.

Here, a region W_2 irradiated with the first shot of pulse laser will be noted in the following description.

FIG. 14 shows a laser irradiated region B poly-crystallized when the a-Si film is irradiated by the second shot of pulse laser. At the second shot, the laser irradiated region B is poly-crystallized by the pulse laser passed through each square pattern 31 of the second mask region M_{12} . The laser irradiated region B is adjacent to a lower edge of the region A poly-crystallized at the first shot.

The laser irradiated region B at the second shot does not undergo any heat influence from the adjacent laser irradiated region. In the laser irradiated region B, the a-Si film is poly-crystallized to have the predetermined or larger crystal particle diameter.

Next, FIG. 15 shows a laser irradiated region C poly-crystallized when the a-Si film is irradiated with

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the third shot of pulse laser. At the third shot, the laser irradiated region C is poly-crystallized by the pulse laser passed through each square pattern 31 of the third mask region M₁₃. The laser irradiated region C is adjacent to a left edge of the laser irradiated region B poly-crystallized at the second shot.

The laser irradiated region C at the third shot does not undergo any heat influence from the adjacent laser irradiated region. In the laser irradiated region C, the a-Si film is poly-crystallized to have the predetermined or larger crystal particle diameter.

Next, FIG. 16 shows a laser irradiated region D poly-crystallized when the a-Si film is irradiated by the fourth shot of pulse laser. At the fourth shot, the laser irradiated region D is poly-crystallized by the pulse laser passed through each square pattern 31 of the fourth mask region M₁₄. The laser irradiated region D is adjacent to an upper edge of the laser irradiated region C poly-crystallized at the third shot.

The laser irradiated region D at the fourth shot does not undergo any heat influence from the adjacent laser irradiated region. In the laser irradiated region D, the a-Si film is poly-crystallized to have the predetermined or larger crystal particle diameter.

Subsequently, the a-Si film is irradiated with the fifth shot of pulse laser. As shown in FIG. 17, a

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laser irradiated region E is poly-crystallized to have the predetermined or larger crystal particle diameter without undergoing any heat influence from the adjacent laser irradiated region.

5 Therefore, for the a-Si film on the glass substrate 10, the non laser irradiated region not irradiated with the pulse laser is successively filled up, and finally the whole surface of the a-Si film on the glass substrate 10 is poly-crystallized.

10 As described, in the second embodiment, the mask 30 is used in which the width of the square pattern 31 has the slit width length to generate the heat gradient in the laser irradiated region obtained when irradiating the a-Si film with the pulse laser, and the
15 pitch is formed in the pitch interval to generate the heat gradient in the laser irradiated region obtained when irradiating the a-Si film with the pulse laser. Thereby, the second embodiment produces an effect similar to the effect of the first embodiment.

20 When the mask 30 is used, a micro crystal region is inevitably generated by irradiation with the fourth shot of pulse laser, and the size of the square pattern 31 remains at 5 μm or less, the pitch may be set to be twice as large as the size of the square pattern.

25 In this case, in order to fill up at least the non-irradiated region with the pulse laser, at least six or more shots of pulse laser beams are necessary,

and the region on the mask 30 is divided into six.

A third embodiment of the present invention will next be described with reference to the drawings.

In the laser processing apparatus of the third
5 embodiment, the constitution of the mask 14 shown in
FIG. 5 is changed. Therefore, the laser processing
apparatus will be described using the laser processing
apparatus shown in FIG. 5.

FIG. 18 is a constitution diagram of a mask 40 for
10 use in the laser processing apparatus.

In the mask 40, a plurality of dotted openings
(hereinafter referred to as a dotted pattern) 41, and a
plurality of ring-shaped openings (hereinafter referred
to as square ring patterns) 42-1, 42-2 are formed.

The dotted pattern 41 and square ring patterns
15 42-1, 42-2 are formed in positions which do not overlap
one another in first to third mask regions M_{21} to M_{23} .

These dotted pattern 41 and square ring patterns
42-1, 42-2 are formed in the respective widths and
20 pitches such that the heat gradient appears at a time
of irradiation of the glass substrate 10 with the pulse
laser.

The constitution of the mask 40 will concretely be
described.

The mask 40 is divided, for example, into first to
25 third mask regions M_{21} to M_{23} . Respective origins Z_{21}
to Z_{23} are set in the mask regions M_{21} to M_{23} .

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In the first mask region M_{21} , the plurality of dotted patterns 41 are formed at the equal pitch in two rows in the Y direction. The dotted pattern 41 is set at such a value that the heat gradient is generated in the laser irradiated region in the a-Si film, for example, such that the beam width of the laser irradiated region on the a-Si film is about 5 μm or less.

In the second mask region M_{22} , the plurality of square ring patterns 42-1 are formed at the equal pitch in two rows in the Y direction. For the square ring pattern 42-1, the size of a square formed inside a ring agrees with the size of the dotted pattern 41. The square ring pattern 42-1 is set at such a value that the heat gradient is generated in the laser irradiated region in the a-Si film, for example, such that the beam width of the laser irradiated region on the a-Si film is about 5 μm or less.

In the third mask region M_{23} , the plurality of square ring patterns 42-2 are formed at the equal pitch in two rows in the Y direction. For the square ring pattern 42-2, the size of the square formed inside the ring agrees with an outer size of the square ring pattern 42-2. The square ring pattern 42-2 is set at such a value that the heat gradient is generated in the laser irradiated region in the a-Si film, for example, such that the beam width of the laser irradiated region

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on the a-Si film is about 5 μm or less.

5 A distance between a center of the dotted pattern 41 and the origin Z_{21} , the distance between the center of the square ring pattern 42-1 and the origin Z_{22} , and the distance between the center of the square ring pattern 42-2 and the origin Z_{23} are substantially the same.

10 Therefore, when the first to third mask regions M_{21} to M_{23} are superposed upon one another, the dotted pattern 41 is disposed in the center, the square ring pattern 42-1 is disposed in the outer periphery of the dotted pattern 41, and the square ring pattern 42-2 is disposed in the outer periphery of the square ring pattern 42-1.

15 The operation of the apparatus constituted as described above will next be described.

20 The method of poly-crystallizing the a-Si film formed on the glass substrate 10 in the manufacturing process of the p-Si TFT liquid crystal display is carried out as follows.

25 The excimer laser 11 intermittently outputs the pulse laser beam, for example, at the repeated frequency of 200 to 500 Hz. The pulse laser is emitted to the mask 40 from the variable attenuator 12 through the lighting optical system 13.

The pulse laser is passed through the mask pattern formed on the mask 40, reaches the mirror 15, and is

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reflected by the mirror 15. The pulse laser reflected by the mirror 15 is emitted onto the a-Si film on the glass substrate 10 by the projection lens 16.

Moreover, similarly as the first embodiment, the XYZ tilt stage 21 continuously moves the glass substrate 10 at the conveyance speed synchronized with the repeated frequency of the pulse laser beam.

The first, second, third, ... shots of pulse laser output from the excimer laser 11 are emitted onto the a-Si film on the glass substrate 10 through the mask 40.

Here, a laser irradiated region a with the pulse laser passed through the dotted pattern 41 of the first mask region M₂₁ will be noted in the following description.

FIG. 19 shows the laser irradiated region a on the a-Si film with the first shot of pulse laser beam passed through the dotted pattern 41.

In the laser irradiated region a, the beam width is 5 μm , and the pitch is equal at 5 μm . In the laser irradiated region a, the crystal grows toward the middle portion from the outer peripheral side, and the whole surface of the laser irradiated region a is polycrystallized. The laser irradiated region a is polycrystallized without undergoing any heat influence from the adjacent laser irradiated region a.

Therefore, the laser irradiated region a is

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poly-crystallized in the predetermined or larger crystal particle diameter.

Next, FIG. 20 shows a laser irradiated region b poly-crystallized, when the a-Si film is irradiated with the second shot of pulse laser passed through the square ring pattern 42-1.

Since the glass substrate 10 continuously moves in the X direction, the laser irradiated region b at the second shot forms the outer periphery of the laser irradiated region a at the first shot. The laser irradiated region b is a square ring pattern having a beam width of 5 μm . The laser irradiated region b is formed at the equal pitch of 5 μm .

Therefore, in the laser irradiated region b, the crystal grows toward the middle portion from the outer peripheral side, and the whole surface of the laser irradiated region b is poly-crystallized. The laser irradiated region b is poly-crystallized without undergoing any heat influence from the adjacent laser irradiated region b. Therefore, the laser irradiated region b is poly-crystallized in the predetermined or larger crystal particle diameter.

Next, FIG. 21 shows a laser irradiated region c poly-crystallized, when the a-Si film is irradiated with the third shot of pulse laser passed through the square ring pattern 42-2.

Since the glass substrate 10 continuously moves in

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the X direction, the laser irradiated region c at the third shot forms the outer periphery of the laser irradiated region b at the second shot. The laser irradiated region c is a square ring pattern having a beam width of 5 μm . The laser irradiated region c is formed at the equal pitch of 5 μm .

Therefore, in the laser irradiated region c, the crystal grows toward the middle portion from the outer peripheral side, and the whole surface of the laser irradiated region c is poly-crystallized. The laser irradiated region c is poly-crystallized without undergoing any heat influence from the adjacent laser irradiated region c. Therefore, the laser irradiated region c is poly-crystallized in the predetermined or larger crystal particle diameter.

As a result, the whole surfaces of the laser irradiated regions a, b, c are poly-crystallized in the predetermined or larger crystal particle diameter by the irradiation with three shots of pulse laser.

Also in the other laser irradiated regions, similarly as described above, the a-Si film is repeatedly irradiated with the pulse laser as shown in FIGS. 19 to 21, and the a-Si film is continuously poly-crystallized.

The a-Si film on the glass substrate 10 is irradiated with the pulse laser passed through the mask 40 in this manner, and the glass substrate 10

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continuously moves by the operation of the XYZ tilt stage 21.

Thereby, when the a-Si film is irradiated with three shots of pulse laser beams, for example, a Si film on the whole surface in the first mask region M₂₁ is poly-crystallized.

Therefore, for the a-Si film on the glass substrate 10, the non-irradiated region with the pulse laser is successively filled up, and finally the whole surface of the a-Si film on the glass substrate 10 is poly-crystallized.

As described above, according to the third embodiment, even when the mask 40 with the plurality of dotted patterns 41 and the plurality of square ring patterns 42-1, 42-2 formed thereon is used, the effect can be produced similarly as the first and second embodiments.

A fourth embodiment of the present invention will next be described with reference to the drawings.

In the laser processing apparatus of the fourth embodiment, the constitution of the mask 14 shown in FIG. 5 is changed. Therefore, the laser processing apparatus will be described using the laser processing apparatus shown in FIG. 5.

FIG. 22 is a constitution diagram of a mask 50 for use in the laser processing apparatus. In the mask 50, a plurality of polygonal pattern openings

(hereinafter referred to as square patterns) 51-1 to 51-3 are formed in longitudinal and lateral directions (XY directions). For the square pattern 51, the width and pitch are formed in such values that the heat gradient appears in the laser irradiated region obtained by irradiating the glass substrate 10 with the pulse laser.

The constitution of the mask 50 will concretely be described.

The mask 50 is divided, for example, into first to third mask regions M_{31} to M_{33} . Respective origins Z_{31} to Z_{33} are set in the first to third mask regions M_{31} to M_{33} .

In the first mask region M_{31} , the plurality of square patterns 51-1 are formed at the equal pitch in two rows in the Y direction. The square pattern 51-1 is set at such a value that the heat gradient is generated in the laser irradiated region in the a-Si film, for example, such that the beam width of the laser irradiated region on the a-Si film is about 5 μm or less.

In the second mask region M_{32} , the plurality of square patterns 51-2 are formed at the equal pitch in two rows in the Y direction. The square pattern 51-2 is smaller than the square pattern 51-1 by a predetermined size. The square pattern 51-2 is set at such a value that the heat gradient is generated in the

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laser irradiated region in the a-Si film, for example, such that the beam width of the laser irradiated region on the a-Si film is about 5 μm or less.

5 In the third mask region M_{33} , the plurality of square patterns 51-3 are formed at the equal pitch in two rows in the Y direction. The square pattern 51-3 is smaller than the square pattern 51-2 by a predetermined size.

10 The square pattern 51-3 is set at such a value that the heat gradient is generated in the laser irradiated region in the a-Si film, for example, such that the beam width of the laser irradiated region on the a-Si film is about 5 μm or less.

15 The distance between the center of the square pattern 51-1 and the origin Z_{31} , the distance between the center of the square pattern 51-2 and the origin Z_{32} , and the distance between the center of the square pattern 51-3 and the origin Z_{33} are the same.

20 Therefore, when the first to third mask regions M_{31} to M_{33} are superposed upon one another, the respective square patterns 51-1 to 51-3 are superposed upon one another in a concentric position.

The operation of the apparatus constituted as described above will next be described.

25 The method of poly-crystallizing the a-Si film formed on the glass substrate 10 in the manufacturing process of the p-Si TFT liquid crystal display is

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carried out as follows.

The excimer laser 11 intermittently outputs the pulse laser, for example, at the repeated frequency of 200 to 500 Hz. The pulse laser is emitted to the mask 50 from the variable attenuator 12 through the lighting optical system 13.

The pulse laser is passed through the mask pattern formed on the mask 50, reaches the mirror 15, and is reflected by the mirror 15. The pulse laser reflected by the mirror 15 is emitted onto the a-Si film on the glass substrate 10 by the projection lens 16.

Moreover, similarly as the first embodiment, the XYZ tilt stage 21 continuously moves the glass substrate 10 at the conveyance speed synchronized with the repeated frequency of the pulse laser beam.

The first, second, third, ... shots of pulse laser beams output from the excimer laser 11 are emitted onto the a-Si film on the glass substrate 10 through the mask 40.

Here, a laser irradiated region T with the pulse laser passed through the square pattern 51-1 of the first mask region M₃₁ will be noted in the following description.

FIG. 23 shows a laser irradiated region K₁ on the a-Si film irradiated with the first shot of pulse laser beam passed through the square pattern 51-1.

In the laser irradiated region K₁, the beam width

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is 5 μm , and the pitch is equal at 5 μm . In the laser irradiated region K_1 , the crystal grows toward the middle portion from the outer peripheral side, and the inside of the laser irradiated region K_1 is poly-crystallized in the predetermined or larger crystal particle diameter. The laser irradiated region K_1 is poly-crystallized without undergoing any heat influence from the adjacent laser irradiated region K_1 .

Additionally, since the heat gradient is small in a middle portion L of the laser irradiated region K_1 , the portion is micro-crystallized.

Next, FIG. 24 shows a laser irradiated region K_2 on the a-Si film irradiated with the second shot of pulse laser passed through the square pattern 51-2.

Since the glass substrate 10 continuously moves in the X direction, the laser irradiated region K_2 at the second shot forms the outer periphery of the laser irradiated region K_1 at the first shot. The laser irradiated region K_2 is a square pattern having a beam width of 5 μm . The laser irradiated region K_2 is formed at the equal pitch of 5 μm .

Therefore, in the laser irradiated region K_2 , the crystal grows toward the middle portion from the outer peripheral side, and the inside of the laser irradiated region K_2 is poly-crystallized in the predetermined or larger crystal particle diameter. The laser irradiated region K_2 is poly-crystallized without undergoing any

heat influence from the adjacent laser irradiated region K_1 .

Additionally, since the heat gradient is small in the middle portion L of the laser irradiated region K_2 ,
5 the portion is micro-crystallized.

Next, FIG. 25 shows a laser irradiated region K_3 on the a-Si film irradiated with the third shot of pulse laser passed through the square pattern 51-3.

Since the glass substrate 10 continuously moves in
10 the X direction, the laser irradiated region K_3 at the third shot forms the outer periphery of the laser irradiated region K_2 at the second shot. The laser irradiated region K_3 is a square pattern having a beam width of 5 μm . The laser irradiated region K_3 is
15 formed at the equal pitch of 5 μm .

Therefore, in the laser irradiated region K_3 , the crystal grows toward the middle portion from the outer peripheral side, and the whole surface of the laser irradiated region K_3 is poly-crystallized. The laser
20 irradiated region K_3 is poly-crystallized without undergoing any heat influence from the adjacent laser irradiated region K_3 . Therefore, the laser irradiated region K_3 is poly-crystallized in the predetermined or larger crystal particle diameter.

As a result, the whole surfaces of the laser
25 irradiated regions K_1 , K_2 , K_3 are poly-crystallized in the predetermined or larger crystal particle diameter

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by the irradiation with three shots of pulse laser.

Also in the other laser irradiated regions,
similarly as described above, the a-Si film is
repeatedly irradiated with the pulse laser as shown in
5 FIGS. 23 to 25, and the a-Si film is continuously poly-
crystallized.

The a-Si film on the glass substrate 10 is
irradiated with the pulse laser passed through the mask
50 in this manner, and the glass substrate 10
10 continuously moves by the operation of the XYZ tilt
stage 21.

Thereby, when the a-Si film is irradiated with
three shots of pulse laser beams, for example, the Si
film on the whole surface in the first mask region M₃₁
15 is poly-crystallized.

Therefore, for the a-Si film on the glass
substrate 10, the non-irradiated region with the pulse
laser is successively filled up, and finally the whole
surface of the a-Si film on the glass substrate 10 is
20 poly-crystallized.

As described above, according to the fourth
embodiment, even when the mask 50 with the plurality of
square patterns 51-1 to 51-3 formed thereon is used,
needless to say, the effect can be produced similarly
25 as the first to third embodiments.

A fifth embodiment of the present invention will
next be described with reference to the drawings.

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In the laser processing apparatus of the fifth embodiment, the constitution of the mask 14 shown in FIG. 5 is changed. Therefore, the laser processing apparatus will be described using the laser processing apparatus shown in FIG. 5.

FIG. 26 is a constitution diagram of a mask 60 for use in the laser processing apparatus. In the mask 60, a plurality of openings (hereinafter referred to as line patterns) 61 are formed in the X direction.

The line pattern 61 is formed in a direction corresponding to the growth direction of the crystal at a time of poly-crystallization of the a-Si film irradiated with the pulse laser on the glass substrate 10.

The constitution of the mask 60 will concretely be described.

The mask 60 is divided, for example, into first to fourth mask regions M_{41} to M_{44} . The first to fourth mask regions M_{41} to M_{44} are divided at an equal interval of the pitch M_p . Respective origins Z_{41} to Z_{44} are set in the first to fourth mask regions M_{41} to M_{44} .

The line patterns 61 are formed in the positions which do not overlap one another in the respective mask regions M_{41} to M_{44} . The width and pitch of the line pattern 61 are formed in such values that the heat gradient is generated in the laser irradiated region in

the a-Si film on the glass substrate 10. For example, the beam width of the laser irradiated region on the a-Si film is about 5 μm or less, and the pitch is 1 μm or more.

5 In the mask region M_{41} , the plurality of line patterns 61 are formed at the equal pitch in the Y direction. The position of one of the line patterns 61 is aligned with the origin Z_{41} .

10 In the mask region M_{42} , the plurality of line patterns 61 are formed at the equal pitch in the Y direction. The line pattern 61 deviates from the line pattern 61 formed in the mask region M_{41} by the width of one line pattern 61.

15 In the mask region M_{43} , the plurality of line patterns 61 are formed at the equal pitch in the Y direction. The line pattern 61 deviates from the line pattern 61 formed in the mask region M_{41} by the width of two line patterns 61.

20 In the mask region M_{44} , the plurality of line patterns 61 are formed at the equal pitch in the Y direction. The line pattern 61 deviates from the line pattern 61 formed in the mask region M_{41} by the width of three line patterns 61.

25 The operation of the apparatus constituted as described above will next be described.

 The method of poly-crystallizing the a-Si film formed on the glass substrate 10 in the manufacturing

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process of the p-Si TFT liquid crystal display is carried out as follows.

5 The excimer laser 11 intermittently outputs the pulse laser, for example, at the repeated frequency of 200 to 500 Hz. The pulse laser is emitted to the mask 60 from the variable attenuator 12 through the lighting optical system 13.

10 The pulse laser is passed through the mask pattern formed on the mask 60, reaches the mirror 15, and is reflected by the mirror 15. The pulse laser reflected by the mirror 15 is emitted onto the a-Si film on the glass substrate 10 by the projection lens 16.

15 Moreover, similarly as the first embodiment, the XYZ tilt stage 21 continuously moves the glass substrate 10 at the conveyance speed synchronized with the repeated frequency of the pulse laser beam.

20 The first, second, third, ... shots of pulse laser output from the excimer laser 11 are emitted onto the a-Si film on the glass substrate 10 through the mask 60.

25 The a-Si film on the glass substrate 10 is irradiated with the pulse laser passed through the mask 60 in this manner, and the glass substrate 10 continuously moves by the operation of the XYZ tilt stage 21.

Thereby, when the a-Si film is irradiated with four shots of pulse laser, the Si film in each laser

irradiated region is poly-crystallized in the predetermined or larger crystal particle diameter by these shots.

5 Since the respective laser irradiated regions with these four shots are adjacent to one another, the whole surfaces of the laser irradiated regions are continuously poly-crystallized.

10 Therefore, for the a-Si film on the glass substrate 10, the non-irradiated region with the pulse laser is successively filled up, and finally the whole surface of the a-Si film on the glass substrate 10 is poly-crystallized.

15 In this case, the polycrystal growth direction is vertical to the movement direction of the glass substrate 10 as shown in FIG. 27. That is, the laser irradiated region obtained by irradiating the a-Si film with the pulse laser beam passed through the line pattern 61 becomes linear.

20 Since the heat gradient increases in a narrower width direction of the laser irradiated region, the crystal grows in the width direction. The width direction is vertical to the movement direction of the glass substrate 10.

25 Additionally, when the mask 14 shown in FIG. 5 is used, the crystal grows in the narrower width direction of the laser irradiated region by the mask 14. The width direction is the movement direction (X direction)

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of the glass substrate 10.

As described above, according to the fifth embodiment, the mask 60 with the plurality of line patterns 61 formed in the X direction thereon is used, and the glass substrate 10 is continuously moved in the X direction.

The whole surface of the a-Si film on the glass substrate 10 can be poly-crystallized in the X direction (movement direction of the glass substrate 10). Therefore, when the mask 60 or the mask 14 shown in FIG. 5 is used, the growth direction of the poly-crystallization on the glass substrate 10 can be controlled.

Additionally, also in the fifth embodiment, needless to say, the effect can be produced similarly as the first to fourth embodiments.

A sixth embodiment of the present invention will next be described with reference to the drawings.

In the laser processing apparatus of the sixth embodiment, the constitution of the mask 14 shown in FIG. 5 is changed. Therefore, the laser processing apparatus will be described using the laser processing apparatus shown in FIG. 5.

FIG. 28 is a constitution diagram of a mask 70 for use in the laser processing apparatus. In the mask 70, a plurality of pattern openings (hereinafter referred to as line patterns) 71 are formed in an oblique

direction with respect to the X and Y directions.

The line pattern 71 is formed in a direction corresponding to the growth direction of the crystal at a time of the poly-crystallization of the a-Si film irradiated with the pulse laser beam on the glass substrate 10, for example, in a direction of 45° with respect to the X direction.

The constitution of the mask 70 will concretely be described.

The mask 70 is divided, for example, into first to fourth mask regions M₅₁ to M₅₄. The first to fourth mask regions M₅₁ to M₅₄ are divided at the equal interval of the pitch M_p. Respective origins Z₅₁ to Z₅₄ are set in the first to fourth mask regions M₅₁ to M₅₄.

The line patterns 71 are formed in the positions which do not overlap one another in the respective mask regions M₅₁ to M₅₄. The width and pitch of the line pattern 71 are formed in such values that the heat gradient is generated in the laser irradiated region in the a-Si film on the glass substrate 10. For example, the beam width of the laser irradiated region on the a-Si film is about 5 μm or less, and the pitch is 1 μm or more.

In the mask region M₅₁, the plurality of line patterns 71 are formed at the equal pitch and inclined, for example, by 45° with respect to the X direction.

The position of one of the line patterns 71 is aligned with the origin Z₅₁.

In the mask region M₅₂, the plurality of line patterns 71 are formed at the equal pitch and inclined, for example, by 45° with respect to the X direction. The line pattern 71 deviates in the Y direction from the line pattern 71 formed in the mask region M₅₁ by the width of one line pattern 71.

In the mask region M₅₃, the plurality of line patterns 71 are formed at the equal pitch and inclined, for example, by 45° with respect to the X direction. The line pattern 71 deviates in the Y direction from the line pattern 71 formed in the mask region M₅₁ by the width of two line patterns 71.

In the mask region M₅₄, the plurality of line patterns 71 are formed at the equal pitch and inclined, for example, by 45° with respect to the X direction. The line pattern 71 deviates from the line pattern 71 formed in the mask region M₅₁ by the width of three line patterns 71.

The operation of the apparatus constituted as described above will next be described.

The method of poly-crystallizing the a-Si film formed on the glass substrate 10 in the manufacturing process of the p-Si TFT liquid crystal display is carried out as follows.

The excimer laser 11 intermittently outputs the

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pulse laser, for example, at the repeated frequency of 200 to 500 Hz. The pulse laser is emitted to the mask 70 from the variable attenuator 12 through the lighting optical system 13.

5 The pulse laser is passed through the mask pattern formed on the mask 70, reaches the mirror 15, and is reflected by the mirror 15. The pulse laser reflected by the mirror 15 is emitted onto the a-Si film on the glass substrate 10 by the projection lens 16.

10 Moreover, similarly as the first embodiment, the XYZ tilt stage 21 continuously moves the glass substrate 10 at the conveyance speed synchronized with the repeated frequency of the pulse laser beam.

15 The first, second, third, ... shots of pulse laser output from the excimer laser 11 are emitted onto the a-Si film on the glass substrate 10 through the mask 70.

20 The a-Si film on the glass substrate 10 is irradiated with the pulse laser passed through the mask 70 in this manner, and the glass substrate 10 continuously moves by the operation of the XYZ tilt stage 21.

25 Thereby, when the a-Si film is irradiated with four shots of pulse laser, the Si film in each laser irradiated region is poly-crystallized in the predetermined or larger crystal particle diameter by these shots.

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Since the respective laser irradiated regions with these four shots are adjacent to one another, the whole surfaces of the laser irradiated regions are continuously poly-crystallized.

5 Therefore, for the a-Si film on the glass substrate 10, the non-irradiated region with the pulse laser is successively filled up, and finally the whole surface of the a-Si film on the glass substrate 10 is poly-crystallized.

10 As shown in FIG. 29, the polycrystal growth direction is vertical to the movement direction of the glass substrate 10. That is, the laser irradiated region obtained by irradiating the a-Si film with the pulse laser beam passed through the line pattern 71
15 becomes linear.

Since the heat gradient increases in the narrower width direction of the laser irradiated region, the crystal grows in the width direction. The width direction is vertical to the movement direction of the
20 glass substrate 10.

As described above, according to the sixth embodiment, the mask 70 is used in which the plurality of line patterns 71 are formed and inclined by 45° with respect to the X direction, and the glass substrate 10
25 is continuously moved in the X direction.

Thereby, the whole surface of the a-Si film on the glass substrate 10 is inclined by 45° with respect to

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the X direction and poly-crystallized. Therefore, also in the sixth embodiment, needless to say, the effect can be produced similarly as the first to fifth embodiments.

5 A seventh embodiment of the present invention will next be described with reference to the drawings.

10 In the laser processing apparatus of the seventh embodiment, the constitution of the mask 14 shown in FIG. 5 is changed. Therefore, the laser processing apparatus will be described using the laser processing apparatus shown in FIG. 5.

FIG. 30 is a constitution diagram of a mask 80 for use in the laser processing apparatus.

15 In the mask 80, for example, four line patterns 81 are formed in the same direction. The width and pitch of the line pattern 81 are formed in such sizes that the polycrystalline Si film having the predetermined or larger crystal particle diameter is formed at the time of the poly-crystallization of the a-Si film irradiated with the pulse laser.

20 The width of each line pattern 81 is formed in a slit width length to generate the heat gradient in the laser irradiated region, when the a-Si film is irradiated with the pulse laser. The pitch between the line patterns 81 is formed in a pitch interval to generate the heat gradient in the laser irradiated region, when the a-Si film is irradiated with the pulse

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laser.

The constitution of the mask 80 will concretely be described.

5 The mask 80 is divided into a plurality of divided regions, for example, first to fourth mask regions M_{61} to M_{64} . Respective origins Z_{61} to Z_{64} are disposed in the mask regions M_{61} to M_{64} . Each interval among these mask regions M_{61} to M_{64} is formed in the interval having the equal pitch M_p .

10 The respective line patterns 81 are formed at the equal distance from the origins Z_{61} to Z_{64} in the mask regions M_{61} to M_{64} . That is, the interval of the line patterns 81 is formed at the equal pitch.

15 The number of line patterns 81 in each of the mask regions M_{61} to M_{64} is not limited to one. When the intervals of all the line patterns 81 of the mask 80 have the equal pitch, a plurality of patterns may be formed in each of the mask regions M_{61} to M_{64} .

20 Each line pattern 81 is formed so that the beam width of the laser irradiated region on the a-Si film is, for example, about $5\ \mu\text{m}$ or less, and the pitch is $1\ \mu\text{m}$ or more. This is the condition for forming the polycrystalline Si film having the predetermined or larger crystal particle diameter.

25 The method of poly-crystallizing the a-Si film formed on the glass substrate 10 in the manufacturing process of the p-Si TFT liquid crystal display is

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carried out as follows.

5 The excimer laser 11 intermittently outputs the pulse laser, for example, at the constant repeated frequency of 200 to 500 Hz. The pulse laser beam is emitted to the mask 80 from the variable attenuator 12 through the lighting optical system 13.

10 The pulse laser is passed through the mask pattern formed on the mask 80, reaches the mirror 15, and is reflected by the mirror 15. The pulse laser reflected by the mirror 15 is emitted onto the a-Si film on the glass substrate 10 by the projection lens 16.

15 Moreover, the XYZ tilt stage 21 continuously moves the glass substrate 10 at the constant conveyance speed synchronized with the repeated frequency of the pulse laser beam. In this case, the conveyance direction is the positive or negative X direction.

Subsequently, the XYZ tilt stage 21 moves the glass substrate 10 in the Y direction by the distance corresponding to the width of the pulse laser beam.

20 Next, the XYZ tilt stage 21 again moves the glass substrate 10 continuously in the X direction at the constant conveyance speed. In this case, the conveyance direction is the negative or positive X direction.

25 Thereafter, the XYZ tilt stage 21 repeats the movement at the constant conveyance speed. The XYZ tilt stage 21 moves the glass substrate 10, for

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example, at the conveyance speed of about 200 to 500 mm/s.

5 The a-Si film on the glass substrate 10 is irradiated with first, second, third, ... shots of pulse laser beams output from the excimer laser 11 through the mask 80.

10 The a-Si film on the glass substrate 10 is irradiated with the pulse laser beam passed through the mask 80 in this manner, and the glass substrate 10 moves at the constant conveyance speed by the operation of the XYZ tilt stage 21.

15 FIG. 31 shows each laser irradiated region F_1 poly-crystallized when the a-Si film is irradiated with the first shot of pulse laser beam. The pulse laser beam passed through each line pattern 81 of the mask 80 is emitted onto the a-Si film on the glass substrate 10. The a-Si film of the laser irradiated region F_1 is poly-crystallized by these pulse laser beams.

20 Each laser irradiated region F_1 is set such that each beam width is 5 μm or less and the pitch M_p is 1 μm or more. Thereby, in each laser irradiated region F_1 , the crystal grows toward the middle portion from the outer edge of the laser irradiated region F_1 , and the whole surface of the laser irradiated region F_1 is
25 poly-crystallized to form the polycrystalline Si film having the predetermined or larger crystal particle diameter.

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Each laser irradiated region F_1 does not undergo any heat influence from the adjacent laser irradiated region, and the a-Si film is poly-crystallized.

Next, FIG. 32 shows a laser irradiated region F_2 poly-crystallized when the a-Si film is irradiated with the second shot of pulse laser beam.

The second shot of pulse laser beam is emitted onto the a-Si film at a timing at which the glass substrate 10 moves by the pitch interval of each line pattern 81.

Therefore, for the laser irradiated regions F_2 of the second shot, three laser irradiated regions F_2 are adjacent to the laser irradiated regions F_1 of the first shot. That is, the laser irradiated regions F_1 and F_2 are formed by the pulse laser beams passed through the different line patterns 81, not by the pulse laser beams passed through the same line pattern 81.

Therefore, even these laser irradiated regions F_2 do not undergo any heat influence from the adjacent laser irradiated region. The laser irradiated region F_2 is obtained by poly-crystallizing the a-Si film in the predetermined or larger crystal particle diameter.

Next, FIG. 33 shows a laser irradiated region F_3 poly-crystallized, when the a-Si film is irradiated with the third shot of pulse laser beam.

The third shot of pulse laser beam is emitted onto

the a-Si film at a timing at which the glass substrate
10 further moves by the pitch interval of each line
pattern 81.

Therefore, for the laser irradiated regions F_3 of
5 the third shot, three laser irradiated regions F_3 are
adjacent to the laser irradiated regions F_2 of the
second shot. Even these laser irradiated regions F_3 do
not undergo any heat influence from the adjacent laser
irradiated region. The laser irradiated region F_3 is
10 obtained by poly-crystallizing the a-Si film in the
predetermined or larger crystal particle diameter.

Here, the respective laser irradiated regions F_1 ,
 F_2 , F_3 , ... of the first, second, third, ... shots of
pulse laser beams have partially overlapped portions
15 g_1 , g_2 as shown in FIG. 34. Even with the overlapped
portions g_1 , g_2 , the a-Si film is poly-crystallized in
the predetermined or larger crystal particle diameter.

Thereafter, similarly as described above, the a-Si
film on the glass substrate 10 is irradiated with the
20 pulse laser beam through the mask 80, and the glass
substrate 10 is moved at the constant conveyance speed
by the operation of the XYZ tilt stage 21.

Therefore, in the a-Si film on the glass substrate
10, the non laser irradiated region not irradiated with
25 the pulse laser beam is successively filled up, and
finally the whole surface of the a-Si film on the glass
substrate 10 is poly-crystallized.

As described above, in the seventh embodiment, the mask 80 with the respective line patterns 81 formed at the equal pitch thereon is used, the glass substrate 10 is moved at the constant conveyance speed, and the pulse laser beam is emitted at the constant timing.

Thereby, for the a-Si film on the glass substrate 10, the non-irradiated region with the pulse laser beam is successively filled up, and finally the whole surface of the a-Si film on the glass substrate 10 is poly-crystallized in the predetermined or larger crystal particle diameter.

An eighth embodiment of the present invention will next be described with reference to the drawings.

In the eighth embodiment, a method of manufacturing the p-Si TFT liquid crystal display using any one of the laser processing apparatuses of the first to seventh embodiments will be described.

FIG. 35 is a constitution diagram showing one example of the TFT liquid crystal display in a manufacturing process. A TFT liquid crystal display 90 includes: a plurality of pixel sections 91; a driver 92 of each pixel section 91 formed around the pixel section 91; and a peripheral circuit 93 including a gate array, D/A converter, and the like.

When the TFT liquid crystal display 90 is manufactured, the a-Si film is formed on the glass substrate of the TFT liquid crystal display 90. On the

a-Si film, the polycrystalline Si film is formed in a region corresponding to the plurality of pixel sections 91, driver 92, and peripheral circuit 93.

For example, a memory and CPU are expected to be
5 directly mounted particularly in the region
corresponding to the driver 92 and peripheral circuit 93. In the region, a property of a film quality is demanded to be enhanced.

To form the polycrystalline Si film in the region
10 corresponding to the plurality of pixel sections 91,
the laser processing apparatus according to any one of
the first to seventh embodiments, for example, the
first embodiment is applied.

The pulse laser beam repeatedly output from the
15 excimer laser 11 is passed through each line pattern 20
of the mask 14 shown in FIG. 2, and emitted onto the
a-Si film corresponding to the pixel section 91 by the
projection lens 16.

On the other hand, the XYZ tilt stage 21
20 continuously moves the glass substrate 10, for example,
in the X direction at the conveyance speed synchronized
with the repeated frequency of the pulse laser beam,
next moves the substrate in the Y direction by a
distance corresponding to a length of the line beam,
25 and subsequently moves the substrate continuously in
the X direction again.

Thereby, the non laser irradiated region of the

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a-Si film forming the pixel section 91 is successively filled up. Finally, the whole surface of the a-Si film on the pixel section 91 is poly-crystallized.

To form the polycrystalline Si film in the region corresponding to the plurality of drivers 92 and peripheral circuits 93, the laser processing apparatus according to any one of the first to seventh embodiments, for example, the first embodiment is applied.

The pulse laser beam passed through the mask 14 is emitted onto the a-Si film corresponding to the driver 92 and peripheral circuit 93 by the projection lens 16. The laser irradiated region is shown as a field 94 of the projection lens 16.

On the other hand, the XYZ tilt stage 21 moves the glass substrate 10 at the conveyance speed synchronized with the repeated frequency of the pulse laser beam. The glass substrate 10 continuously moves in a direction extending along a longitudinal direction of the driver 92 and peripheral circuit 93, for example, in the Y direction (or the X direction).

Finally the whole surface of the a-Si film on the driver 92 and peripheral circuit 93 is poly-crystallized by scanning the pulse laser beam.

FIG. 36 is a constitution diagram showing one example of another TFT liquid crystal display in the manufacturing process.

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A TFT liquid crystal display 100 includes: a plurality of pixel sections 101; a plurality of drivers 102 formed around the respective pixel sections 101; and a plurality of peripheral circuits 103 including the gate array, D/A converter, and the like.

A size of the driver 102 or the peripheral circuit 103 is formed to be smaller than a size of the field 94 of the projection lens 16.

To form the polycrystalline Si film in the region corresponding to the pixel sections 101 of the TFT liquid crystal display 100, the laser processing apparatus according to any one of the first to seventh embodiments, for example, the first embodiment is applied.

The pulse laser beam repeatedly output from the excimer laser 11 is passed through each line pattern 20 of the mask 14 shown in FIG. 6, and emitted onto the a-Si film corresponding to the pixel section 101 by the projection lens 16.

On the other hand, the XYZ tilt stage 21 continuously moves the glass substrate 10, for example, in the X direction at the conveyance speed synchronized with the repeated frequency of the pulse laser beam, next moves the substrate in the Y direction by the distance corresponding to the length of the line beam, and subsequently moves the substrate continuously in the X direction again.

Thereby, the non laser irradiated region of the a-Si film forming the pixel section 101 is successively filled up. Finally, the whole surface of the a-Si film on the pixel section 101 is poly-crystallized.

5 To form the polycrystalline Si film in the region corresponding to the plurality of drivers 102 and peripheral circuits 103, the laser processing apparatus according to any one of the first to seventh embodiments, for example, the first embodiment is applied.

10 The pulse laser beam passed through the mask 14 is emitted onto the a-Si film corresponding to the driver 102 and peripheral circuit 103 by the projection lens 16.

15 On the other hand, the XYZ tilt stage 21 moves the glass substrate 10 at the conveyance speed synchronized with the repeated frequency of the pulse laser beam. The glass substrate 10 continuously moves in a direction extending along a longitudinal direction of the driver 102 and peripheral circuit 103, for example, in the Y direction (or the X direction).

20 Finally the whole surface of the a-Si film on the driver 102 and peripheral circuit 103 is poly-crystallized by scanning the pulse laser beam.

25 As described above, according to the eighth embodiment, the regions corresponding to the plurality of pixel sections 91, 101, drivers 92, 102, and

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peripheral circuits 93, 103 in the TFT liquid crystal displays can be poly-crystallized.

Particularly the properties of the film qualities of the regions corresponding to the drivers 92, 102 and peripheral circuits 93, 103, on which the memory and CPU are expected to be directly mounted, can be enhanced.

In the TFT liquid crystal display 100 shown in FIG. 36, the size of the driver 102 or the peripheral circuit 103 is formed to be smaller than the size of the field 93 of the projection lens 16. Therefore, the overlap in the irradiation with the pulse laser beam can be reduced. A capability of the polycrystalline Si film can be enhanced.

In the eighth embodiment, all the regions corresponding to the plurality of pixel sections 91, 101, drivers 92, 102, and peripheral circuits 93, 103 are poly-crystallized. This is not limited. For example, only regions for forming semiconductor devices such as CPU and memory may be poly-crystallized in the regions of the drivers 92, 102 and peripheral circuits 93, 103.

A ninth embodiment of the present invention will next be described with reference to the drawings.

FIG. 37 is a schematic constitution diagram of an exposure device such as a stepper. A laser device 110 outputs a laser beam for subjecting a work 111 to an

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exposure processing. The work 111 is, for example, the glass substrate of the liquid crystal display.

5 A lighting optical system 112 and mirror 113 are disposed on an optical path of the laser beam. A mask 114 and image forming lens system 115 are disposed on a reflected light path of the mirror 113. The lighting optical system 112 shapes the laser beam output from the laser device 110 and uniforms a light strength.

10 A plurality of pattern openings are formed in the mask 114. The width and pitch of the pattern opening is set to a value, for example, in accordance with the exposure processing of the glass substrate 111 of the liquid crystal display. For example, the mask 14 shown in FIG. 6, mask 30 shown in FIG. 12, mask 40 shown in
15 FIG. 18, mask 50 shown in FIG. 22, mask 60 shown in FIG. 26, mask 70 shown in FIG. 28, and mask 80 shown in FIG. 30 can be applied to the mask 114.

20 An XYZ stage 116 has the glass substrate 111 mounted thereon, and moves the glass substrate 111 in the XY directions and Z direction. The XYZ stage 116 moves the glass substrate 111 by each predetermined distance in one direction.

25 When the XYZ stage 116 moves the glass substrate 111 by each predetermined distance, the respective laser irradiated regions on the glass substrate 111 irradiated with the laser beams passed through the pattern openings of the mask 114 do not overlap one

another.

The operation of the apparatus constituted as described above will next be described.

5 As the mask 114, for example, the mask 14 shown in FIG. 6 is applied.

10 For example, in the manufacturing process of the p-Si TFT liquid crystal display, the thin a-Si film is formed on the glass substrate 111, and the thin film is coated with a resist and subjected to the exposure processing. Thereafter, the manufacturing process includes image developing, etching processing, and removing of the resist.

15 The exposure device of the ninth embodiment is used in the exposure processing during the manufacturing process.

The first shot of laser beam output from the laser device 110 is shaped and uniformed by the lighting optical system 112. The laser beam is reflected by the mirror 113, and emitted onto the mask 114.

20 The laser beam is passed through the line pattern 20 of the mask 114, and emitted onto the glass substrate 111 of the liquid crystal display by a projection lens system.

25 FIG. 38 shows a linear exposed region and exposure strength by the first shot of laser beam. The surface of the glass substrate 111 is coated with a resist film. The resist film is subjected to the exposure

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processing in the exposed region having an exposure strength higher than a resist exposure threshold value.

Subsequently, the XYZ stage 116 moves the glass substrate 111 by a distance corresponding to the half of the pitch of the line pattern of the mask 114. The movement direction of the glass substrate 111 is vertical to the longitudinal direction of the line pattern 20 of the mask 114.

Next, the laser device 110 outputs the second shot of laser beam. The laser beam is shaped and uniformed by the lighting optical system 112, and reflected by the mirror 113. The laser beam is passed through the line pattern 20 of the mask 114 and emitted onto the glass substrate 111 by the projection lens system.

FIG. 39 shows the linear exposed region and exposure strength by the second shot of laser beam. The glass substrate 111 is subjected to the exposure processing in the exposed region having the exposure strength higher than the resist exposure threshold value. The exposed region of the second shot is formed in each interval between the exposed regions of the first shot.

As a result, a linear pattern is transferred to the resist on the glass substrate 111 by the second exposure processing as shown in FIG. 36.

Additionally, when the plurality of line patterns formed on the mask 114 are used to perform the resist

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exposure processing, and each interval between the line patterns is narrowed, the line pattern cannot be resolved by the vicinity of a resolution limit by the projection lens system.

5 Therefore, as shown in FIG. 41, the exposure strength continuously becomes higher than the resist exposure threshold value. Thereby, the exposed region of the line pattern does not appear. Therefore, the resist on the glass substrate 111 is exposed by a broad
10 pattern.

 Even in this case, according to the eighth embodiment of the present invention, even when the exposed region of the line pattern is narrowed, each exposed region can be resolved and the exposure
15 processing can be performed. The linear pattern, which has not heretofore been achieved, can be transferred onto the glass substrate 111 with precision and at high resolution.

 For example, the respective laser irradiated
20 regions do not completely overlap one another, and the mask is formed so that a part of the laser irradiated region has the overlapped portion. This mask may be used to perform the laser processing and exposure. Even in this case, the effect of the present invention
25 can be obtained.

 The openings formed in the masks 13, 30, 40, 50, 60, 70, 80 and 114 explained in the first to ninth

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embodiments may be any holes thorough which the light such as a pulse laser can passes. For example, a phase shift mask may be used as the mask having these openings.

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